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UTILIZATION OF FULL WEIGHT LOAD CAPACITY OF RR FREIGHT CARS

[Comment: This report is a full translation of an article in Chinese prepared by the translation office of the Ministry of Railways, that was published in Jen-min T'ieh-tao (People's Railways) 1952, No 10, 15 October 1952. The text was based on a lecture before a class of Chinese trainees delivered by Zadorozhniy, a Soviet railroad adviser at Harbin. For convenient use, the following glossary of terms and symbols is included.

Glossary of Terms and Symbols

Still load -- the dead weight of the cargo in a car at rest.

Mean transit load -- The average (weight) load on a car throughout the movements of one turnaround period, ascertained by computation using still load and ton-kilometrage data for each car.

Pcm	-- average (still load) carload.
ΣP	-- total or aggregate weight of cargo.
u	-- number of loaded cars involved.
n	-- number of cars in operation, loaded and empty.
Prp	-- mean transit load of loaded cars.
L	-- kilometrage.
ΣPL	-- total ton-kilometrage.
Σnsrp	-- total kilometrage of loaded cars in terms of car-kilometers.
Σnsnop	-- total kilometrage of empty cars in terms of car-kilometers.
Σns	-- total kilometrage of all cars in operation.
PO	-- mean transit load of cars in operation.
Pnod	-- the weight load capacity of a freight car.
Krp	-- (weight) loading coefficient of a car.
ECK	-- empty car-kilometrage.
LCK	-- loaded car kilometrage.
TCK	-- total car-kilometrage.
a	-- empty car-kilometrage percentage.
Eb	-- car output rate. This is the index of the amount of productive work per car per day, in terms of ton-kilometers; is equivalent to the total net ton-kilometers per day of all cars in operation divided by the number of cars in operation.

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S -- daily car-kilometrage of one car.
Sb -- daily car kilometrage of all cars in operation.
R -- average number of cars in daily operation.
Pmex -- planned normal load; or technical standard (still) load.
G -- specific weight of commodity or cargo.
e -- range of variation of specific weights of any one commodity.
Kb -- coefficient of space utilization; equivalent to the ratio between the actual space occupied by cargo and the total space in the car.
On -- space capacity of car.
Ow -- volume of goods or cargo piled up above the side walls of a car.
Om -- space in car occupied by heavy goods, when car contains a mixed load.
Pm -- weight of heavy goods in a car with mixed load.
Pd -- weight of light goods in a car with mixed load.
Gm -- specific weight of heavy goods.
Gd -- specific weight of light goods.
Od -- space occupied by light goods.]

A very important problem for the railways to consider is how to perform the planned transportation task with the minimum numbers of cars. One way is to shorten the turnaround time; but it is of equal importance to utilize the full weight and space capacity of each car. High-grade performance in this matter depends to a great extent on skillful loading. Are the best rational loading methods employed, such as those developed by Yang Mao-lin? Is the best practice being observed with respect to the manner of packing and measurements of packages? Are the most suitable types of cars being used for the various kinds of cargo?

Reference to the data for average carload gives the simplest indication of the degree to which full-capacity loading is being realized. But there are two ways of speaking of the load of a car; the still load, and the mean transit load. When the loads on the cars of a train are evenly distributed, and are not changed while in transit, the average still-load carload [Pcm] may be found by using the formula $Pcm = \frac{\sum P}{u}$, where $\sum P$ is the total weight of the cargo, and u is the number of loaded cars involved.

The weight of still-load carloads depends on the nature and properties of the cargo, regardless of the car capacity and distance to be traveled. This being the case, the weight of the still load can only indicate what proportion of the weight-carrying capacity of the car at rest, is being used; it cannot fully indicate whether that proportion of carrying capacity is used throughout the whole course of the car's turnaround journey. The relation of the mean transit load to the weight-carrying capacity of the car can give a more accurate indication of the degree of utilization of the car's carrying capacity. To ascertain the mean transit load, we must know the number of ton-kilometers (net load) for each car-kilometer of loaded cars or cars in operation.

The mean transit load of loaded cars [Prp] may be calculated by using the formula: $Prp = \frac{\sum PL}{\sum nsrp}$ where $\sum PL$ is the total ton-kilometrage for the period under consideration, and $\sum nsrp$ is the total kilometrage of the loaded cars in terms of car-kilometers.

The mean transit load of cars in operation [PO] (including empty cars) may be calculated by using the formula: $PO = \frac{\sum PL}{\sum nsrp + \sum nsnop} = \frac{\sum PL}{\sum ns}$, where $\sum nsnop$ stands for the total kilometrage of empty cars, and $\sum ns$ is the total kilometrage of all cars in use (including loaded and empty cars).

Consider an example of the calculation of the average load for a given bureau. The following diagram indicates a number of stations, A,B,C,D,E, and K, and their distances from each other in kilometers; and the accompanying table indicates the amount in tons, origin, and destination of a number of shipments.

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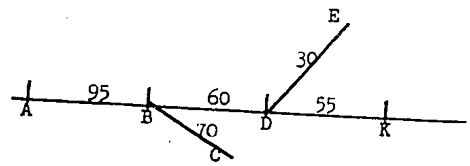

Movements	Distances	Tons of Cargo	No of Cars	Ton-Kilometers	Car-Kilometers	Average Carloads
A → C	165	4,200	200	693,000	33,000	21.00
A → E	185	4,200	220	777,000	40,700	19.09
A → K	210	4,100	180	861,000	37,800	22.80
B → K	115	1,800	100	207,000	11,500	18.00
E → A	185	4,800	220	888,000	40,700	21.80
E → C	160	3,000	150	480,000	24,000	20.00
K → E	85	1,200	90	102,000	76,500	13.24
K → A	210	--	150	--	31,500	13.24←[sic] [-]
K → E	85	--	150	--	12,750	13.24←[sic] [-]
Totals	--	23,300	1,460	4,008,000	239,600	13.24←[sic] [16.70]

The average still load per car, $Pcm = \frac{\Sigma P}{\Sigma n}$ is $\frac{23,300}{1460}$: 20.1 [sic] tons. [As the fraction $\frac{23,300}{1,460}$ stands, the quotient should be 15.95 tons; and this figure would be the average still load per car for all cars in operation (Σn). If the formula $Pcm = \frac{\Sigma P}{u}$ is used, the fraction would be $\frac{23,300}{1,160} = 20.1$ tons, which would be the average still load per loaded car. It appears that the point being made below is that the average load as calculated by taking kilometrage into account gives a more accurate indication of the degree of utilization of cars, than by reckoning merely the still loads on cars.]

The average in transit load per car for loaded cars is $\frac{\Sigma PL}{\Sigma nsrp} = \frac{\text{ton-kilometers}}{\text{car-kilometers}} = \frac{4,008,000}{195,350} = 20.52$ tons.

The average in transit load for all cars in use, loaded and empty, is

$$PO = \frac{\Sigma PL}{\Sigma nsrp + \Sigma nsnop} = \frac{\Sigma PL}{\Sigma ns} = \frac{\text{ton-kilometers}}{\text{car-kilometers}} = \frac{4,008,000}{239,000} = 16.7 \text{ tons.}$$

The figures used in the foregoing example are those of two-axle cars with a very small percentage of four-axle cars.

The average still load indicates only the number of tons loaded, or transported, on a car, and the proportion of the car's weight load capacity that is being used. The ratio [Krp] between the average still load of a car [Pcm], and the weight load capacity of the car [Pnod], may be considered and used as the loading coefficient of the car.

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Factors that affect the degree of utilization of cars such as the speed of operation, the loading coefficient, and the percentage which the empty-car kilometrage [ECK] is of the loaded car kilometrage [LCK], appear in the composite index which is called the car output rate. The car output rate, for a certain day [Eb], is the portion performed by one car of the net ton-kilometrage performed on that day by all the cars in operation.

$$Eb = \frac{\Sigma PL}{n} = \frac{\Sigma PL x Sb}{\Sigma nsrp\ (1+a)} = \frac{PO\ x\ Sb}{(1+a)} = Prp\ x\ Sb$$

In this formula, Sb stands for the daily car-kilometrage of the cars in operation.

$$S = \frac{\Sigma ns.}{R} \qquad Prp = \frac{\Sigma PL}{\Sigma nsrp}$$

The car output rate has a decisive effect on the number of cars required to transport the quantity of cargo that must be transported. The relationship may be seen in the formula: $R = \frac{\Sigma PL}{Eb}$, where R stands for the average number of cars in daily operation.

The normal (weight) load of a car is determined as follows:

The normal load of a car for different kinds of cargo depends on the following factors: the size, shape, and weight capacity of the car, the size and weight of the individual packages of the cargo, and the manner in which they are stowed in the car. Calculation of the tentative normal load capacity of a car should be made separately for each type of car and each type of cargo. The rules to be observed in testing the tentative normal load of a car are those worked out by Yang Mao-lin and formulated in his loading method. To carry out the tests, summarize, and reach proper conclusions from the results of tests, consideration of the following matters is essential:

1. Knowledge of the technical characteristics of the cargo, whether it is fragile, able to withstand heavy pressure, or malodorous.

2. Knowledge of technical weight-carrying capacity of the car that is being tested.

3. Investigation of new methods of loading or stowing cargo in or on the car.

4. Experimentation with test samples of cargo of larger units and weight and method of packing, such as greater degree of compression of cotton, different wrappings, etc.

5. Decision on rules governing weight and height of cargo pile to be adopted for the purposes of the tests.

6. Decision as to the respective methods of loading for the various kinds of cargo tested and determination of the technical loading quota for each.

The loading tests for various kinds of cargo, the results of which are to be the basis for determining the normal loads of cars, should be carried out under the supervision of a commission organized by the Ministry of Railways and composed of representatives of the railway bureaus or subbureaus concerned and of the parties interested in the industry that produces the products requiring transportation. The results of these tests are to be recorded by this commission. In order that the load carrying capacity of cars for various categories of cargo may be more fully utilized, consistent with safety, the Ministry of Railways should issue special regulations for the loading of gondola cars.

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The normal load adopted should not be merely the average of ordinary loadings, but rather should be the average of the loadings which are packed closely and stowed by men who practice the progressive Stakhanovite principles. The normal load is to be based on the technical conditions that pertain to the loading of a particular kind or type of cargo, conditions that are formulated in the course of the tests which should be approved when the normal load is approved and adopted. Concerning the technical loading conditions, the following points should be made clear:

1. Type of car best suited to the cargo to be transported in order to utilize most fully the weight-carrying capacity of the cars.

2. Sort of packing and wrapping most suitable for the cargo.

3. Loading methods selected for normal loads of particular kinds of cargo. These should be recorded, and their observance required.

4. Permissible height goods may be piled up when loading open cars, and whether to ridge, or to round the top.

5. Precautions to be taken against damage to cargo.

6. Best ways for assuring the security of goods in transit.

When the normal load is being determined for different types of goods, special attention should be given to the matter of how the correct specific weight of goods may be ascertained. The specific weight of goods depends on their substance, brand, and moisture content. Due to these varying characteristics, it is necessary to divide cargoes into different categories. But to avoid too many fine distinctions, a limit of specific weight variation has been adopted, namely from 50 to 100 chin (one chin equals 1.1. pounds).

To ascertain by calculation the normal load for covered cars for a given commodity, the following formula may be used:

$Pmex = On \times Kb \times (G + \frac{e}{2})$, where Pmex is the planned normal load; G is the specific weight of the commodity, expressed in tons per cubic meter, for the lightest specimens of each type of cargo; and e stands for the range of specific weight variation. Kb is the coefficient of space-utilization per car; and On is the total space capacity of the car. $G + \frac{e}{2}$ is the average specific weight of the commodity based on the applicable range of variation.

For a gondola car, use the formula:

$Pmex = (On + Ow) \times (G + \frac{e}{2})$, where Ow stands for the volume of goods piled up above the side walls of a gondola.

The principal methods for better utilization of the weight carrying capacity of cars are: (1) by increasing compression of such goods as cotton, straw, hemp, sheet metal, or by crushing or pulverization; (2) by careful stowing of cargo, per Yang Mao-lin's methods; (3) by use of thin, light, not bulky, wrappings or containers; (4) by use of the knockdown method, such as complete or partial disassembling of machines; (5) by wide use of containers; (6) by intelligent loading of suitable proportions of light and heavy cargo; (7) by calculating the dimensions of the car and the dimensions of the articles or individual packages, so that they may be stowed evenly or in the most advantageous manner; (8) when transporting certain kinds of cargo, by raising the sides of the gondola to permit piling to an increased height; and (9) by ascertaining exact weight of the cargo and exact normal load of the car.

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The kinds of cargo transported by rail vary greatly in density or specific weight. When moving heavy goods, the full weight-carrying capacity of a car is generally used while its space capacity is not fully used; and when moving light-weight goods, the reverse is the case -- although the content of the car is fully occupied, the full weight carrying capacity is not fully utilized. Mixed loading, that is, heavy and light goods in the same car, may greatly raise the degree of utilization of carrying capacity, if done intelligently. Such mixed loading is permissible, subject to the nature of the goods. To derive the maximum advantage from mixed loading, it is necessary to ascertain the relative specific weights of the two kinds of goods, and then the average specific weight of the combination of goods must be equal to the unit weight load capacity of the car. The weight of the heavy goods [Pm] may be found by using the formula:

$$Pm = \frac{Pnod - (On \times G)}{1 - \frac{Gd}{Gm}},$$

where On is the space capacity of the car; Gd is the specific weight of the light goods; Gm is the specific weight of the heavy goods. The weight of the light goods, Pd is then equal to Pnod - Pm.

Let us by the application of the above formula, calculate the amount of light and heavy goods that make up a mixed load which fully uses the space and weight capacity of a car.

Let the weight capacity of the car [Pnod] be 20 tons;

Let the space capacity of the car [On] be 45 cubic meters;

Let the specific weight of the heavy goods be 0.82 tons per cubic meter;

Let the specific weight of the light goods be 0.22 tons per cubic meter.

Then,

$$Pm = \frac{20 - 45 \times 0.22}{1 - \frac{0.22}{0.82}} = 13.84 \text{ tons.}$$

The weight of the light goods will be 20 - 13.84 = 6.16 tons. The amount of space occupied by the heavy goods is $Om = \frac{Pm}{Gm} = \frac{13.84}{0.82} = 17.0$ cubic meters.

The space occupied by the light goods is $Od = \frac{Pd}{Gd} = \frac{6.16}{0.22} = 28$ cubic meters.

The proper placing of goods in the car has a great deal to do with the full utilization of a car's carrying capacity with regard to both weight and space. Suppose a full carload lot of goods is to be transported in a 20-ton car whose length is 1,360 millimeters, width 620 millimeters, and height 330 millimeters, and the weight of each box is 125 kilograms. If, when placing the boxes in the car, their long dimension is placed parallel with the length of the car, the width of each box in line with the width of the car, and the thickness of each box in line with the vertical height of the car, then the number of boxes that can be placed in this fashion is as indicated in the following table:

	Dimensions of Car (mm)	Dimensions of Boxes (mm)	No of Boxes Placeable	Unoccupied Space
Length	6,600	1,360	4	1,160
Width	2,750	620	4	270
Height	2,500	330	7	190

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The total number of boxes placeable is thus 4 x 4 x 7 = 112 boxes. The weight of the load is 112 x 125 = 14,000 kilograms or 14 tons. The proportion of utilization of weight capacity is $\frac{14}{20}$ = 70 percent.

If, however, the width of the boxes is made to lie in line with the length of the car, and the length of the boxes across the width of the car, then the placing will be: 6,600 ÷ 330 = 20 boxes in the length of the car (no unoccupied space); 2,750 ÷ 1360 = 2 boxes in the width of the car (30 mm unoccupied space); and 2500 ÷ 620 = 4 boxes in the height of the car 20 mm unoccupied space. The total number of boxes placeable is then 20 x 2 x 4 = 160 boxes. The weight of the load is 160 x 125 = ~~20,000~~ kilograms = 20 tons, which is full capacity. Thus, there was an increase of 30 percent in the utilization of the weight carrying capacity of the car, and a great reduction in the waste space.

A convenient way to ascertain the most suitable dimensions for packaged goods and the most advantageous way to place them in the car, is to prepare a space loading table similar to the following table.

Space Loading Table for a 40 ton car (dimensions in millimeters)

No of boxes	1	2	4	8	12	16
Length	12,640	6,320	3,166	1,580	1,053	790
Width	2,667	1,333	666	333	222	166
Height	2,375	1,187	543	296	197	148

If the dimensions of the boxes are 3,166 x 333 x 197 millimeters, and they are properly placed, the number placeable will be 4 x 8 x 12 = 384 boxes, with a minimum of waste space, and the maximum load weight based on the weight of the goods (including containers) per unit of volume.

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